SOME ECOSYSTEM RESPONSES TO EUROPEAN WILD BOAR ROOTING IN A DECIDUOUS FOREST

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TABLE OF CONTENTS

ABSTRACT

The influence of rooting by European wild boar (*Sus scrofa*) upon surface fauna, nutrients and biomass of forest litter and soil was investigated in the northern hardwood forest of Great Smoky Mountains National Park, 1979-1980. Rooting by wild boar mixed A_1 and A_2 soil horizons and reduced ground vegetative cover and leaf litter. Two vertebrates that depend largely on leaf litter for habitat, the red backed vole (*Clethrionomys gapperi*), and short-tailed shrew (*Blarina brevicauda*), were nearly eliminated from intensely rooted stands. Two other mammals and five salamanders that preferred more arboreal or subterranean habitats were unaffected by the rooting. Rooting accelerated the leaching of Ca, P, Zn, Cu, and Mg from leaf litter and soil. Nitrate concentrations, however, were higher in soil, soil water, and stream water from the rooted stands, suggesting alterations in ecosystem nitrogen transformation processes. Rooting did not increase sediment yield, apparently because of the high infiltration rate of southern Appalachian soils, and because the disturbance further promoted infiltration through decreased bulk density.

SOME ECOSYSTEM RESPONSES TO EUROPEAN WILD BOAR ROOTING IN A DECIDUOUS FOREST

INTRODUCTION

Rooting by European wild boar (Sus scrofa L.) is suspected of accelerating the decomposition of organic matter by incorporating forest litter into the soil (Jezierski and Myrcha 1975). Rooting biocenoses are believed to promote tree growth for pines planted on poor soils in western Europe (Koehler 1954; Mrozowski 1966; Andrezejewski and Jezierski 1978), but experimental data on soil effects is lacking. Past impact studies have focused on possible reductions in plant cover (Spatz and Mueller-Dombois 1972; Bratton 1974, 1975; Howe and Bratton 1976; Baron 1979), effects on beech (Fagus spp.) sprouting (Bjerke 1957; Huff in press), and possible effects on subterranean foods (Skinner et al. 1976; Howe et al. 1981).

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Bratton (1975) postulated that the increase in bare ground after rooting could accelerate soil erosion.

Effects of pig disturbance has worldwide implications on forest ecosystems and on agricultural lands during depredations on crops (Dombrowski 1896; Boback 1957; Andrezejewski and Jezierski 1969; Mackin 1970; Roberts 1977: 163-166). European wild boar, due to their adaptability, high reproductive rate and secretive nature, still occupy much of their original range in Europe, Asia, and North Africa. In the U.S., all true swine are exotic, and are more likely to be disruptive to ecosystems not adapted to them. Feral pigs, European wild boar, and crosses between both types (all S. scrofa L.) now occupy significant portions of eleven states. Feral pig populations are relatively stable in the southeastern coastal plain and in Hawaii, but are rapidly expanding in Texas and California (Wood and Lynn 1977; Wood and Barrett 1979), and the wild boar is invading new range in a NNW direction in North Carolina and Tennessee at about 2.5 km/yr (Singer 1981). The purpose of this investigation was to document the effects, if any, of rooting by exotic wild boar upon the soil, forest floor, and suface nutrients of the most intensively rooted forest type in Great Smoky Mountains National Park (GSMNP). Study period was 1979-1980.

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METHODS

Study Area We conducted our studies in the northern hardwood forest type in GSMNP. This forest type is restricted to a narrow band about 0.35 km wide that runs along the central ridgecrest of the park. Rainfall averages 225 cm and temperatures 8 C annually. Tree basal area averages 37 m^2/ha, of which 62% is American beech (*Fagus grandiofolia*); 21% maples (*Acer saccharum*, *A. rubrum*); 10% yellow birch (*Betula lutea*); and 7% others (Russell 1953). The forest floor is composed of decaying leaves and humus totalling from 3 to 15 cm deep. Understory shrubs are few, stands are relatively open, and herb diversity and coverage is high (Russell 1953, Whittaker 1956, Bratton 1975). Wild boar migrate from low elevation oak forests annually to the northern hardwoods, and between April and August root approximately 80 percent of the forest floor surface area in their search for herbs, subterranean tubers and macroinvertebrates.

Five stands, reprsenting a range in rooting history, were studied. Two stands were intensely disturbed after initial invasions 8 and 18 years ago and presently support summer densities of 7 to 9 animals/km^2. One stand was lightly rooted by 1-3 animals (<1 animal/km^2) for 4 years (F. Singer, unpubl. data). The remaining two stands were located in the southeastern

quarter of the Park not yet occupied by wild boar. Aspect for all 5 stands was NE-NW, and elevations ranged between 1517 to 1668 m. All soils were weak grade, fine class, granular structure, and loam texture (Wolf, J.A. 1967. Forest soil characteristics as influenced by vegetation and bedrock in spruce-fir zone of the Great Smoky Mountains. Unpubl. Ph. D. Thesis, Univ. Tennessee, Knoxville. 132 pp.) and were classified as Ramsey-like soils but in the Sol Brun Acide great soil group (McCracken et al. 1962). Soil horizons A, AB, B_2, and B_3 were recognizable at each stand, and horizon were of similar width between stands (X±95%C.I. for $A_1+A_2=6.6\pm2.4$cm, $B_2=13.3\pm4.0$cm and $B_3=12.6\pm2.9$cm). Depth to bedrock, however, varied from 36 cm to several meters. Bedrock was primarily feldspathic sandstones.

Resampling of 1965 Soil Pits. At one stand, we obtained before-and-after rooting data from soil pits described in 1965 (Wolfe 1967). Wild boar first invaded Double Springs Gap in 1971 (Susan Bratton, pers. comm.) Wolfe's 1965 pits were relocated and new sampling stations established about 1 m from them. Percent plant cover and percent bare ground were estimated above each pit. Similar to Wolfe (1967), we described profiles using Munsell color notations and terminology of the Soil Survey Manual (Soil Survey Staff 1962). The width of each horizon was measured to the nearest 0.1 cm, and samples from 0_1 and 0_2 litter and each soil horizon were collected and placed in numbered boxes (N=6 samples per pit).

Soil and Nutrient Pool Sampling. In each stand, two 10x10 m plots were selected for sampling. One was located on the relatively flat crest of the ridge, the other 60 m downslope. Each plot was gridded into 100 1 x 1 m squares, and from these, 10 were selected from a random numbers table. Depth of the forest floor was measured to the nearest 0.1 cm at five random points, percent plant cover and percent bare ground were estimated, and branches and leaves were bagged separately and oven-dried at 100 C for 24 hours. Where litter was mixed with A_1 soil in the rooted sites, humus was separated from soil prior to bagging. A soil pit was located 25 cm from the west side of every other square (n=5 pits per plot). Bulk density (gms/cm_3) was determined for each soil horizon as was pH, N, Ca, Cation Exchange Capacity, Mg, K, Na, Mn, and additionally, Cu, Zn, Fe, B for litter samples (Jackson 1964) and organic matter by loss on ignition, NO_3-N, P by N_aHCO_3-P, K, Mg, Ca, and Na (Black 1965). Horizons A_1 and A_2 were lumped because of extensive mixing. We also sampled soil and litter inside and outside an exclosure protected for 3 years from rooting at the stand occupied for 18 years. Soil and litter collections were made in August, 1979.

Litter Disturbance. Another 18 plots of 10 x 10 m were randomly selected, and the disturbance of branches and logs by wild pigs was recorded. Each downed branch or tree trunk <2.5 cm in diameter was counted, and its length and mid-length diameter was measured in order to estimate woody volume. We recorded whether the branch had been moved or rolled by wild boar during

the current season. We also recorded the number of freshly exposed tree roots $\geq$1 m from the base of a tree, and measured their exposed length and diameter.

Surface Dwelling Vertebrates. Small mammals were live-captured in 25 x 8 x 7 cm traps set at each of the five forest stands for 5-8 trap nights. A total of 50 traps were set on a 5 x 5 m permanently marked grid. Trapping was conducted once each season for one year.

Terrestrial salamanders were sampled from five 10 m x 10 m plots randomly located in each stand. Salamanders were captured by hand after turning over branches, logs, and leaf litter. Because of the disturbance associated with this technique, we conducted one sampling at each forest stand during Jul - Aug of both 1979 and 1980.

Nutrient Inputs and Discharges. Two of the five forest stands were selected for watershed studies; one intensely rooted (Double Springs Gap) and one undisturbed (Sugartree Licks Gap). The watersheds were about 0.2 ha in size and were readily delineated by topographic boundaries. Rainfall was measured near each watershed and bulk precipitation samples were collected for chemistry analysis. A 30 cm H-flume and a 60 cm Coshocton wheel were installed to sample stream runoff in proportional to the flow (Douglass and Swift 1977, following Parsons 1954). Four pairs of porous cup lysimeters were installed in each watershed

at depths of 30 and 100 cm. Precipitation, stream, and lysimeter samples were collected weekly Nov 1979-Oct 1980 and analyzed for pH, suspended solids, Na, Ca, K, Mg, SO, Cl, PO_4, N, NO_3-N, NH_4-N and Kjeldahl-N by analytical methods of the Coweeta Hydrologic Lab (Anonymous 1980).

RESULTS AND DISCUSSION

Resampling of 1965 Soil Pits. Significant changes occurred to the hebaceous vegetation and forest floor at Double Springs Gap 8 years after occupation by wild boar. Plant cover was reduced an average of 80%, bare ground increased 88%, and the O_1 litter layer was reduced 64% in depth (Table 1). A_1 and A_2 horizons were recognized in 1965 but were mixed and indistinguishable after perturbation. Vertebrate tunnels were common throughout A_1 and A_2 horizons in 1965, but were not observed in 1979.

Forest Litter Disturbance. The depth of the forest floor and weight of leafy material were reduced by 65% and 59%, respectively, in intensely rooted stands but woody (branch) litter was not significantly different (t-test, $P<0.05$, Table 2). Leafy litter increased 51% inside the pig exclosure after three years ($t=3.86$, $P<0.05$), while woody litter was unchanged. In the lightly rooted stand, litter biomass and nutrient values were not significantly different from unrooted sites and were pooled with the pristine data. This small stand is surrounded by

Table 1. Comparison of soil pit characteristics at Double Springs Gap 6 years before and 8 years after wild boar occupation (*=Significant difference, $\underline{P}<0.05$, paired t-tests).

Variable	Prior to Occupation	After Occupation by Wild Boar
Percent plant cover	92.6	12.2 *
Percent bare ground	0.0	87.8 *
No. dominant herbs species	7.0	3.0
Width O_1 Horizon (cm)	2.8	1.0 *
Width O_2 Horizon (cm)	1.1	1.2
Width A_1 Horizon (cm)	6.1	Mixed with A_2
Width A_2 Horizon (cm)	9.7	Mixed with A_1
No. Pits w/ vertebrate tunnels, A_1	4	0 *
No. Pits w/vertebrate tunnels, A_2	3	0 *

Table 2. Litter and surface disturbance by European wild boar in 5 northern hardwood forest stands (*N* = 100 plots of 1 m^2).

Variable	Intensely Rooted (N=40)	Lightly Rooted (N=20)	Pristine (N=40)
Percent plant cover	10	64	41
Percent bare ground	16	2	0
Depth of Forest floor (0_1+0_2 horizons in cm)	1.2	2.6	3.4
Weight Leafy litter(kg/ha)	1830	2420	3095
Weight woody litter(kg/ha)	2055	1810	2500
No. exposed tree roots/ha	2800	0	0

a spruce-fir forest unattractive to pigs and is exceptional in the lightness of rooting.

In the intensely rooted stands, 67% of all branches and logs >2.5 cm diameter were moved by wild boar and another 10% were broken apart (total=77% disturbed, Fig. 1). Only the very largest logs, >400 cm^3 in volume, were not disturbed.

Wild boar rooting exposed 1,400-2,800 tree roots per ha, excluding those naturally exposed roots occurring within 1 m of tree trunks. The exposed roots ranged from 1.3 to 12.7 cm in diameter and from 7.6 to 149 cm in length. Four percent of the exposed roots were broken. Exposure of roots apparently stimulated sprouting of American beech (38% of all exposed roots had at least one beech sprout), which supports the conclusion of Bjerke (1957) for rooting effects in European beech forests.

<u>Surface Vertebrates</u>. Red-backed voles and short-tailed shrews were common in pristine stands but absent from trap samples in intensely rooted stands (N = 0 captures during 666 trap nights in rooted stands, N = 58 captures during 897 trap nights in pristine stands $P < 0.05$). White-footed mice (*Peromyscus maniculatus* and *P. leucopus*) were trapped 28% more often in the intensely disturbed stands and chipmunks (*Tamias striatus*] 66% more often, respectively, but the differences were not statistically significant (Chi-square test for unpaired variates, $P > 0.95$). Red-backed voles and shrews are ubiquitous in GSMNP and specimens were collected in pre-wild boar invasion years near our study sites (Lindzey and Lindzey 1971).

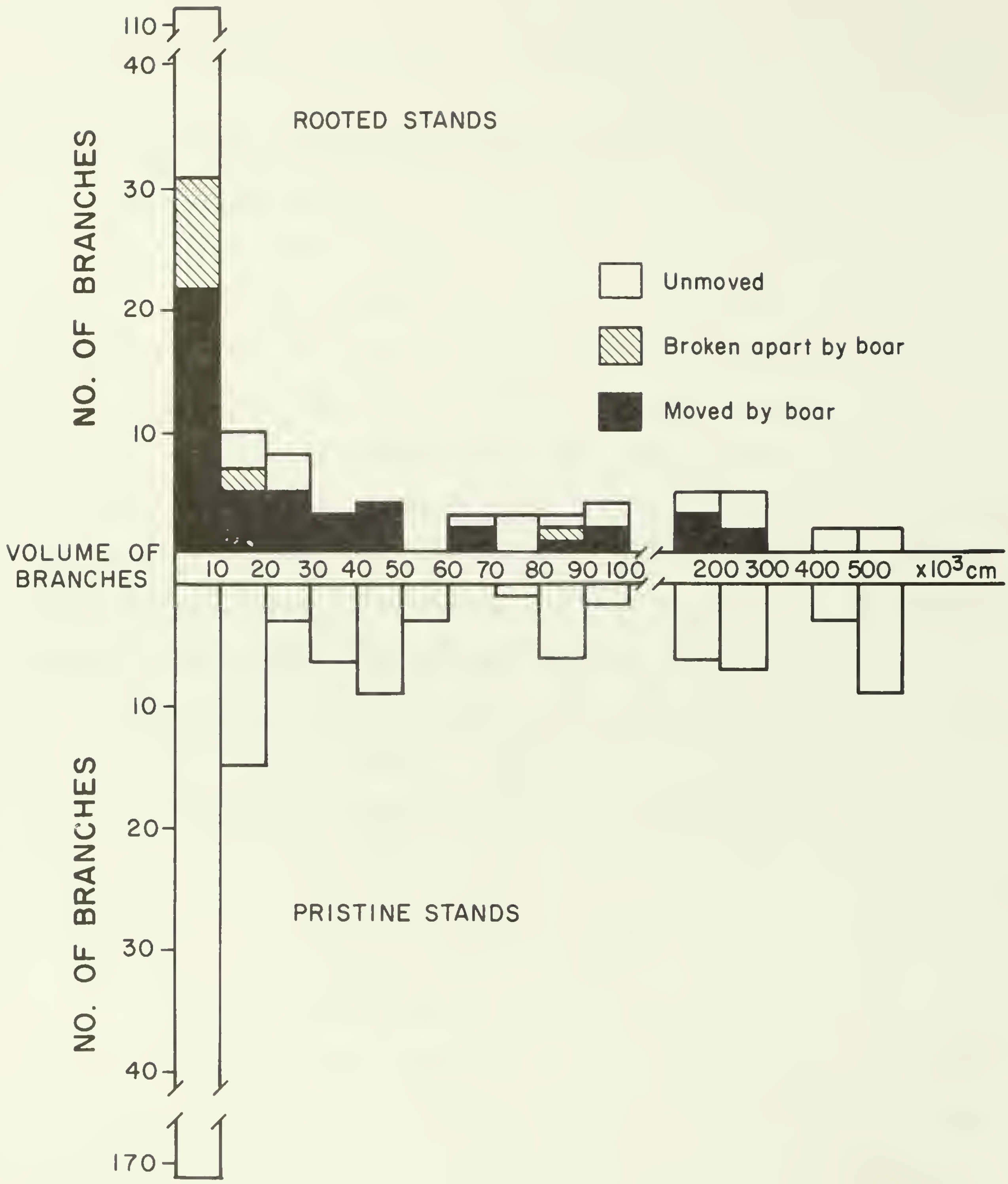

Fig. 1. Comparison of size distributions of branches and logs moved or broken apart by wild boar during rooting of forest stands (_N_=18 plots of 10 x 10 m in each forest stand).

Red-backed voles are surface-tunneling rodents and apparently disturbance of the leaf litter layers and moving of logs destroyed their habitat. Shrew response may have either been similarly habitat related or due to the 80% decline in macroinvertebrate food sources in rooted stands (Howe et al. 1981). White-footed mice are semiarboreal and their habitat may be less influenced by the wild pig rooting. Red-backed voles climb stumps <1.5 m but cannot readily cross between trees and do not display either arboreal travel or nesting habits (Getz and Ginsberg 1968).

We found no significant difference in salamander numbers between pristine and rooted stands ($\underline{P}$ >0.95). We collected five species, Plethodon jordani, Desmognathus ochrophaeus, D. wrightii, and Eurycea bislineata (Conant 1975). An average of 12 salamanders were collected per 100 m^2 plot in rooted stands and 15 in pristine stands. Collections in 1980, an exceptionally dry and hot summer, declined 63% from 1979 numbers in both rooted and pristine areas, probably because terrestrial salamanders are increasingly subterranean under dry conditions (Taub 1961) and more difficult to collect. Salamanders may find adequate alternate habitats in rooted areas such as on vegetation (Hairston 1949), in soil refugia (Taub 1961) and inside or under the larger logs that were not disturbed by wild boar. Also, we collected some salamanders in disturbed leaf litter indicating it is still acceptable habitat.

Nutrient Concentrations in Litter and Soil. Wild boar

rooting apparently accelerated decomposition and loss of nutrients from the forest floor and upper soil horizons (Table 3). Differences were consistent in $O_1 + O_2$, A and AB horizons, but not at lower. Ca, P, Mg, Mn, Zn, Cu, H, and Cation Exchange Capacity were lower in the rooted stands (ANOVA $P<0.01$). However, concentrations of S, Fe, and B in the forest litter and organic matter and K in both litter and soil were not different between disturbed and pristine stands ($\underline{P} > 0.95$). Nitrogen concentrations in the forest litter were less in the intensively rooted stands, suggesting leaching, but NO_3-N and NH_4-N were greater in the disturbed soil ($\underline{P} < 0.05$) indicating alteration in nitrogen transformation processes. Nutrients in fresh leaf fall paralleled the soil trends; Ca, K, and Mg were lower in leaves ($\underline{P} < 0.05$) Nutrient concentrations in leaf fall generally correlate with those in decomposing leaf tissue and the forest floor (Gosz et al. 1972).

Nutrient concentrations recovered slightly inside the exclosure after three years. P, Cu, and S in the litter, and P, Mg, and K in the soil averaged 27% higher than immediately outside the exclosure ($\underline{P} < 0.05$), while there was no significant difference for N, NO_3-N, Mg, K, Mn, Zn, in litter and NH_4-N, organic matter, and Ca in soil ($\underline{P} > 0.95$). Increases in the nutrient pool of the litter occurred, however, since litter biomass increased 51%.

The order of abundance of elements in the leafy forest floor was N>Mg>Ca>Mn>S>Al>Fe>P>K>Na>B>Cu (Table 4). This order of abundance, with the exception of S, was not altered in the

Table 3. Concentrations of nutrients in several components of northern hardwood forest. Differences were tested with ANOVA (*=$\underline{P}$<0.01).

Elements	Pristine (ppm)	Intensely Rooted (ppm)	
N in fresh leaf fall	1,595	1,980	*
N in 0_1 and 0_2 litter	24,000	19,100	*
NO_3-N in A soil horizon	19	29	*
NH_3-N in AB soil horizon	10	19	*
NH_4-N in A soil horizon	132	188	*
Ca in fresh leaf fall	850	510	*
Ca in 0_1 and 0_2 litter	11,250	5,900	*
Ca in A soil horizon	90	56	*
Ca in AB soil horizon	56	29	*
P in fresh leaf fall	65	95	
P in 0_1 and 0_2 litter	1,490	1,190	*
P in A soil horizon	58	32	*
P in AB soil horizon	50	14	*
K in fresh leaf fall	700	155	*
K in 0_1 and 0_2 litter	1,060	1,070	
K in A soil horizon	67	89	
Mg in fresh leaf fall	120	85	*

Table 3. (continued)

Elements	Pristine(ppm)	Intensely Rooted(ppm)	
Mg in O_1 and O_2 litter	11,990	6,190	*
Mg in A soil horizon	34	25	*
Mg in AB soil horizon	15	12	*
Mn in fresh leaf fall	1,318	1,130	
Mn in O_1 and O_2 litter	11,990	1,024	*
Zn in fresh leaf fall	40	41	
Zn in O_1 and O_2 litter	84	34	*
Cu in fresh leaf fall	13	14	
Cu in O_1 and O_2 litter	84	34	*
S in fresh leaf fall	130	130	
S in O_1 and O_2 litter	1,800	1,860	
Fe in fresh leaf fall	195	364	
Fe in O_1 and O_2 litter	1,751	1,861	
Na in fresh leaf fall	20	20	
Na in O_1 and O_2 litter	110	160	*
Organic matter (%) A horizon	15.6	16.7	
Cation Exchange Capacity (me/100g)	25	21	*

disturbed stands even though total content was greatly reduced. Reduction in the biomass of the forest floor greatly magnified the reduction in nutrient conctentrations (Table 4). Nutrient ratios are extremely important in forest ecosystems.

Soil Erosion. Rooting decreased bulk density of soil. Ridgetop bulk densities in rooted stands averaged 0.51 compared to 0.61 gms/cm^3 in pristine stands, while downslope bulk densities were 0.63 and 0.74 gms/cm^3, respectively (paired t-test, P <0.05).

Sediment yield was not increased by the perturbation; total suspended solids averaged 34 mg/l in the rooted compared to 48 mg/l for the undisturbed watershed (t-test, P <0.05). Even though considerable bare soil was present on rooted sites, the loam soils of the southern Appalachians are extremely porous to falling rain (Patric 1976), and the decreased bulk density from rooting apparently further encouraged rapid infiltration by water. Increased erosion in eastern deciduous forests is typically associated with more severe soil disruptions such as bulldozed roads (Patric 1976) or with soil compaction (Packer 1953; Legg and Schneider 1977). Our watershed slopes were ≤20% and perhaps losses could occur on steeper slopes.

Precipitation, Soil Water, and Stream Chemistry. Water sampling indicated major alterations in nitrogen transformation processes in the rooted watershed. Soil water solutions at both the 30 cm and 100 cm levels in the disturbed watershed were

Table 4. Element content of leafy material in the forest floor of stands intensely rooted by wild boar and in pristine stands, Great Smoky Mountains National Park.

Element	Pristine (Kg/ha)	Intensely Rooted Kg/ha)
N	66	35
Mg	33	11
Ca	31	11
Mn	7	4
S	6	3
Al	4	4
Fe	4	3
P	4	2
K	3	2
Na	0.3	0.3
Zn	0.2	0.06
B	0.04	0.02
Cu	0.03	0.01

significantly higher in NO_3-N, Kjeldahl N, and K (Table 5). Inorganic forms of nitrogen input from precipitation were slightly higher in the rooted watershed (Table 5), however, the values were not significantly different and accelerated release from nitrogen pools is indicated. Due to drought conditions during 1980, only 8 stream samples were collected from the pristine watershed which precluded statistical comparisons. NO_3-N in stream water from the rooted site was double that from the undisturbed drainage which at least suggests a trend parallel with soil water. Concentrations of other nutrients were similar both in precipitation and surface waters (Table 5).

CONCLUSIONS AND IMPLICATIONS

Three independent sampling programs all demonstrated substantial reductions in plant cover, reductions in the O_1 litter layer, and mixing of the A_1 and A_2 soil horizons due to wild pig rooting. Comparisons between stands and across an exclosure fence indicated that rooting reduced P, Mg and Cu, did not effect K, and increased soil water nitrate levels. Stand comparisons indicated reductions in Mn, Zn, H, and Cation Exchange Capacity, but these were not indicated in the exclosure comparison. Erection time for the exclosure was only three years which is perhaps an inadequate time for significant nutrient recovery. The elements P, Ca, and K are likely to be influenced by differences in parent material and bedrock weathering rates. However, the similarities between precipitation inputs, between

Table 5. Average annual concentration of selected nutrients in solution for pristine and intensely rooted northern hardwood forest watersheds. Differences were tested with analysis of ANOVA (*=$\underline{P}$<0.05; **=$\underline{P}$<0.01). Sample period was Nov 1979-Oct 1980, Great Smoky Mountains National Park.

Sample Type Nutrient (Unit)	Pristine (Sugartree Licks Gap)	Intensely Rooted (Double Springs Gap)	
Precipitation			
NO^3-N (mg/l)	0.18	0.27	
NH_4-N (mg/l)	0.21	0.49	
Dissolved Kjeldahl N (%)	0.27	0.24	
Particulate Kjeldahl N (%)	1.64	1.60	
K (mg/l)	0.20	0.18	
Ca (mg/l).08	0.28	0.39	
PO_4-P (mg/l)	0.08	0.06	
Depth (cm)	111	193	
No.of Samples	36	260	
Lysimeters (30 cm)			
NO_3-N (mg/l)	2.78	6.38	**
NH_4-N (mg/l)	0.03	0.03	

Table 5. (Continued)

Nutrient (Unit)	(Sugartree Licks Gap)	(Double Springs Gap)	
Dissolved Kjeldahl N(mg/l)	0.13	0.30	**
K (mg/l)	0.92	1.56	**
Ca (mg/l)	2.79	3.76	
PO_4-P (mg/l)	0.01	0.004	
Lysimeters (100 cm)			
NO_3-N (mg/l)	3.83	6.58	**
NH_4-N (mg/l)	0.02	0.03	*
Dissolved Kjeldahl N(mg/l)	0.17	0.25	*
K (mg/l)	1.43	1.94	*
Ca (mg/l)	3.29	3.81	
PO_4-N (mg/l)	0.01	0.004	
No. of Samples	52	26	
Stream Water			
NO_3-N (mg/l)	0.73	1.50	
Suspended Solids (mg/l)	0.48	0.34	
No. of Samples	8	38	

several less significant ions (Cu, S, Na, and Fe) in the upper soil horizons, and between significant nutrients in lower soil horizons, all support the assumption that our comparisons were a meaningful index to perturbation effects.

Northern hardwood forest stands may be particularly vulnerable to accelerated leaching. Fine roots occur primarily in the upper forest floor, and nutrient cycling is largely restricted between there and the vegetation (McCracken et al. 1962). The characteristic deep litter layer is in part due to very slow breakdown of American beech leaves (Shanks and Olson 1961) which is greatly accelerated by mechanical breaking during rooting Normally beech leaves remain unfragmented for the first year after fall (Shanks and Olson 1961).

Potential fates of leached nutrients includes increased uptake and storage or recycling by vegetation and/or loss from the watershed in runoff. Any runoff of leached nutrients occurred prior to the 8-year sampling of the rooted watershed, since only itrate concentrations were higher there. This pattern supports our contention that nitrate alterations were process-oriented and ongoing, while other ion changes were due to accelerated litter breakdown. Annual litterfall likely contributes to the current stable runoff rates for other nutrients since litterfall may account for 8-10% of the total nutrient pool in a deciduous forest (Rodin and Basilevic 1967), and up to 25% of the total forest floor weight (Olson 1963). Nitrification-denitrification alterations from rooting are currently under investigation. Possible factors involved include

greater ammonification from increased air to bacteria surface area, and accelerated nitrification due to more frequent freezing of the more exposed soil surface in rooted watershed (Bormann and Likens 1979).

Progressive losses of nitrates in stream runoff could result in reduced plant growth, productivity and above ground biomass if the values decline below a limiting value threshold. This thinking is inconsistent with the speculation by west-European foresters that wild pig rooting promoted tree growth, although rooting responses may vary in a pine forest. Research on plant growth responses to wild pig rooting are needed in a variety of forest ecosystems. Until growth rate data are available, we recommend a conservative approach to wild pig introductions into northern hardwood forest or any other habitat where high, uncontrolled densities might be reached as in GSMNP.

SUMMARY

1. A study was conducted during 1979 and 1980 into the possible impacts of rooting by European wild boar upon forest floor and soil properties, soil nutrients, surface dwelling vertebrates and sediment runoff in streams.
Soil, rodent and salamander collections were made during Jul and Aug while stream, lysimeter and rain collections were made about each 7 days for one year.

The study was a cooperative effort between the Uplands Field Lab of Great Smoky Mountains National Park (National Park Service, USDI) and Coweeta Hydrologic Lab (USDA, Forest Service), with participation by the Botany Department, University of Tennessee. Uplands Lab conducted the field collections and sampling and provided overall organization. Coweeta performed the water sample analysis and organization, while the University of Tennessee organized the soil collection procedures and provided field expertise in soils.

2. Comparisons were made using three independent sampling programs. Soil pits and soil data had been collected at Double Springs Gap in 1965, 6 years prior to first invasion of the site by wild pigs. We returned to the same pits and collected comparative samples in 1979, after 8 years of heavy rooting. Our second program involved comparative data collected at rooted northern hardwood stands and apparently similar sites as yet unoccupied by wild boar. A third

program consisted of comparisons inside and outside of an exclosure.

3. Red-backed voles and short-tailed shrews were not collected in rooted stands, but white-footed mice, chipmunks, and all 5 salamanders species (two-lined, pygmy, red-cheeked, imitator, and Blue Ridge Mountain) were equally abundant in disturbed and pristine stands. The greater dependence of voles and shrews upon surface habitat is suspected to be the reason for their decline. The other species are known to include either more arboreal and/or more subterranean refugia in their habitat selections.

4. Rooting greatly reduced plant cover and forest litter, mixed the A_1 and A_2 soil horizons, and the pigs moved 67% of all downed branches and logs.

5. Wild boar rooting apparently accelerated the decomposition and loss of nutrients from the forest floor. Ca, P, Mg, Mn, Zn, Cu, H and Cation Exchange Capacity were consistently lower in rooted stands while S, Fe, B, and organic matter were not different. On the other hand, NO_3-N and NH_4-N were greater in the soil and in stream water from the rooted watershed. We suspect that the greater exposure of soil to air during rooting either accelerates the nitrification process and/or slows denitrification. Also, the disturbed soil apparently freezes more often during winter which increases nitrates.

6. Sediment loads were not increased in the rooted watershed, apparently because of the high infiltration rate of the loamy soils

involved and because rooting decreased soil bulk density, thereby further promoting infiltration by rainfall.

FUTURE RESEARCH

1. The National Park Service is presently continuing investigations into rooting impacts. In 1981, a contract study of tree growth effects was initiated, and Uplands Lab personnel erected five permanent cyclone fence enclosures (10x20 m) to further document recovery rates. Nirification-denitrification process alterations are being investigated by Coweeta and Uplands Lab personnel under an award from the Man the the Biosphere Program (MAB).
2. The nitrate losses we documented are inconsistent with the speculation by west-European foresters that wild pig rooting promoted tree growth. This suggest that either the European hypothesis was invalid or that rooting responses may vary in a pine forest. Nutrient responses should be documented in other forest ecosystems.

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